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# INSTRUCTION MANUAL

## PEN FUNCTION AMPLIFIER

MODEL PFA 22

SERIAL NO. 70

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INSTRUCTION MANUAL

PEN FUNCTION
AMPLIFIER

MODEL PFA 22

SERIAL NO. 70

Third Edition

April 1961

CHANGE NOTICE

INSTRUCTION MANUAL

PEN FUNCTION AMPLIFIER, MODEL PFA 22

THIRD EDITION, APRIL 1961

| Component | Pages | Was | Changed To |
|---|---|---|---|
| CR5-2 | 11, 15 | TJ40A | 1N3079 |
| J4-2 | 11, 15 | 97-3106A-145-65 | MS3106A-14S-6S |
| R19-2 | 12, 15 | 47 ohms | 68 ohms |

MODEL PFA 22

PEN FUNCTION AMPLIFIER

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# MODEL PFA 22

# PEN FUNCTION AMPLIFIER

## I. GENERAL DESCRIPTION

### 1.1 Introduction

The Model PFA 22 Pen Function Amplifier is a miniature plug-in unit designed for use with the Series APR 30 polar and the Series APR 20 pattern recorders. This unit together with the proper pattern recorder plug-in potentiometer determines the pattern recorder pen function. The Model PFA 22 Pen Function Amplifier provides a logarithmic pattern recorder pen function. The Model P-3 logarithmic plug-in potentiometer must be used with the pattern recorder to obtain a logarithmic pen response.

The pen function amplifier accepts an amplitude modulated audio carrier at a frequency between 400 and 2500 cps. This signal is normally supplied by either a crystal-bolometer amplifier or a dc-chopper preamplifier.

A signal level meter, located on the front panel of the pen function amplifier, provides monitoring of the signal at the amplifier input over an 80 db dynamic range. The meter has a 40 db scale and is logarithmically calibrated to correspond to both a linear recorder input and a square-law recorder input. A step attenuator and a variable attenuator provide the additional dynamic range.

### 1.2 Specifications

| | |
|---|---|
| Pen Function | Logarithmic |
| Input Impedance | 2200 ohms |
| Signal Input for Full Scale Pen Deflection | 8 - 10 volts rms |

| | |
|---|---|
| Signal Level Meter Calibration | |
| Referred to linear input | 0 db to 40 db |
| Referred to square-law input | 0 db to 20 db |
| Signal Level Meter Calibration Accuracy | |
| 40 db range | ± 1 db |
| 20 db range | ± .5 db |
| Signal Level Meter Attenuation* | |
| Fixed | 20 db |
| Variable | 20 db |

* Attenuation referred to square-law input.

## II. OPERATING INSTRUCTIONS

### 2.1 Logarithmic Pen Function

To provide a logarithmic pattern recorder pen response, insert the Model P-3 Logarithmic Potentiometer in the proper position in the recorder head. The pattern recorder is now properly connected to provide a logarithmic pen response.

A zero set adjustment is not provided since the recorder pen will normally seek a null position below the lower excursion of the chart scale when zero signal input is applied to the recorder.

The DAMPING CORRECTION adjustment provides a means of equalizing the upscale and downscale recorder pen deflection caused by non-linear pen function. Adjustment of the DAMPING CORRECTION control is accomplished as follows:

a. Apply sufficient signal to input preamplifier of the recorder to provide greater than half-scale pattern recorder pen deflection.

b. Turn the DAMPING CORRECTION control fully conterclockwise.

c. Operate the step attenuator on the preamplifier to introduce both and upscale and downscale pen step.

d. Reduce the amount of pen servo amplifier TACHOMETER control to obtain overshoot of the recording pen at the end of both the upscale and the downscale pen stops. This overshoot will be much larger at the end of the upscale step.

e. Set the DAMPING CORRECTION adjustment for equal overshoot at the ends of both the upscale and downscale pen steps.

f. Reset the pen servo amplifier TACHOMETER control for minimum overshoot and undershoot at the ends of the upscale and downscale pen steps.

## 2.2 Signal Level Meter

The logarithmically calibrated meter and associated attenuators located on the front panel of the pen function amplifier provide monitoring of the signal appearing at the amplifier input. The 40 db dynamic range of the meter together with a 40 db fixed attenuation step and 40 db of variable attenuation provide metering of the signal over the full dynamic range of signal level which may be recorded. This meter is useful to provide signal level indication when initially adjusting the signal source modulation frequency, for setting the received power level and to aid in locating the main lobe of the antenna pattern. In addition, the meter may be used for vswr measurements.

The meter is provided with two logarithmic scales: the black scale is calibrated to indicate relative signal strength when using a linear detector; the red scale is calibrated to indicate signal strength when using a square-law detector.

## 2.3 Full Scale Adjustment

The FULL SCALE ADJUST potentiometer (P22-2), accessible at the rear of the pen function amplifier chassis, provides adjustment of the overall gain of the amplifier. This adjustment is initially set to provide the specified full scale sensitivity of the overall pattern recorder. This adjustment should be reset as the tubes age to maintain the proper full scale sensitivity.

## III. DETAILED DESCRIPTION

### 3.1 Input Circuit

A circuit diagram of the Model PFA 22 Pen Function Amplifier is located at the rear of this manual.

The input signal to the pen function amplifier is coupled through P1-2, pin D. Pin D furnishes a high level signal from the 600 ohm winding of the output transformer of the plug-in preamplifier.

A block diagram of the basic circuit is provided in the Model APR 20 and Model APR 30 Instruction Manuals.

The high level signal from the preamplifier appearing at pin D of P1-2 is coupled to the METER ATTENUATOR switch (S1-2). This switch either couples the signal directly to the METER GAIN potentiometer (R4-2) or to the 20 db fixed attenuator consisting of R1-2, R2-2, R3-2, R4-2 and R6-2. The variable arm of the METER GAIN potentiometer is coupled through R5-2 to the grid of the first half of V1-2. The fixed and variable attenuators are designed to provide a constant load of approximately 100 k ohms to the applied signal. R5-2 isolates the grid of the first half of V1-2 from the input line to prevent loading if the applied signal level is sufficient to cause grid current to flow.

The impedance provided by the signal level meter attenuator network and amplifier must remain constant to prevent a change in the loading of the input signal which determines the position of the recording pen.

V1-2 is a two-stage fixed gain resistance coupled amplifier which drives the SIGNAL LEVEL meter through the meter rectifiers (CR1-2 and CR2-2). The METER CALIBRATION POTENTIOMETER (R14-2) is provided to permit calibration of the meter using an external attenuator. The adjustment screw of R14-2 is located on the terminal board at the top, inside of the amplifier, behind the meter.

The input signal is connected through J2-2 to the logarithmic potentiometer. The signal from the center arm of the logarithmic potentiometer is connected to the grid of the first half of V2-2 and the signal applied to the grid is logarithmically attenuated proportional to the shaft position of the logarithmic potentiometer.

### 3.2 Intermediate Stages

The first and second halves of V2-2 are resistance coupled amplifiers providing a total voltage gain of 41 db. The FULL SCALE ADJUST potentiometer, located in the grid circuit of the second half of V2-2, provides approximately 6 db of gain adjustment. This permits initial adjustment of the recorder full scale sensitivity and periodic readjustment as required. V3-2 is a resistance coupled amplifier and a transformer coupled amplifier employing degenerative feedback to obtain good linearity with an output signal level in excess of 100 volts peak. The overall gain of these two stages is 50 db. The high level output of T1-2 is applied to the rectifier and filter combination consisting of CR5-2, R43-2, C11-2, R42-2, and C12-2. Because of the high level of the applied signal, a detector linearity to better than 1% of full output is obtained. The RC filtering provided is sufficient to eliminate carrier frequencies between 400 cps and 2500 cps, yet permitting adequate low frequency response to obtain a recorder pen speed of 40 inches-per-second.

### 3.3 Output Circuit

The negative dc output of the half-wave rectifier (CR5-2) is summed with a positive reference signal and the difference voltage is coupled to the pen servo amplifier through Pin A of P1-2. Since balancing is obtained by positioning the logarithmic potentiometer which precedes the amplifier, the level of the voltage at the output of CR5-2 is constant (-34 volts) when the

system is nulled. The diode (CR6-2), in series with the potentiometer (R48-2), provides a means of equalizing the slopes of the positive and the negative error signal which are unequal because of the logarithmic pen response. For a rectified signal greater than the reference voltage, the error signal is a negative; thus the diode (CR6-2) conducts placing R48-2 in parallel with the series combination of R41-2 and R40-2. For a resultant positive error signal, diode (CR6-2) is an open circuit removing R48-2 from the circuit. With this arrangement, the DAMPING CORRECTION potentiometer (R48-2) can be adjusted to equalize the slopes of the positive and negative error signals.

### 3.4 Filament and Plate Power

All filament and plate voltages are furnished to the pen function amplifier through P1-2. All tube filaments in the pen function amplifier are fed by a -12 volt supply. A total filament current of 0.45 ampere is required by these tubes.

The +250 volt potential is applied to the plates of all amplifiers. This voltage is obtained from the +250 volt regulated supply which furnishes plate potential throughout the pattern recorder.

## VI. MAINTENANCE

### 4.1 General

In the event of faulty operation of any part of the pen function amplifier, a visual inspection of tubes, cable connections and other components should be completed first. Afterwards, standard maintenance procedures should be followed to isolate the trouble to a particular stage and then to the defective component. To aid in the maintenance, the circuit diagram provides typical plate voltages and current values, component values and part numbers. In addition, the following voltage and gain tables provide a means of testing the static and dynamic circuit operation.

### 4.2 Static Measurements

The following table provides typical values of dc voltages present at the tube pins of the amplifier stages. These voltages are measured with respect to ground using a 20,000 ohm-per-volt voltmeter. These voltages are subject to standard tolerances of ±10%. During measurement of pattern recorder Pen Motor ON-OFF switch and the preamplifier ATTENUATOR should each be in the OFF position.

TABLE I DC VOLTAGES

| Tube Number | Pin Number | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| V1-2 | +112 | 0 | +1 | 0 | -12 | +175 | 0 | +0.83 | -6 |
| V2-2 | +62 | 0 | +1.2 | 0 | -12 | +85 | 0 | +1.8 | -6 |
| V3-2 | +226 | 0 | +.7 | 0 | -1.2 | +.47 | 0 | +.4 | -6 |

## 4.3 Dynamic Measurements

The following table provides typical values of voltage-gain-per stage for the pen function amplifier. These measurements were made with a 1000 cps signal applied first to pin 2 of V1-2 and then to pin 2 of V2-2.

TABLE II GAIN

| Gain Measured | | Voltage Gain (db) |
|---|---|---|
| From | To | |
| Pin 2, V1-2 | Pin 7, V1-2 | 34 |
| Pin 7, V1-2 | Pin 6, V1-2 | 20 |
| Pin 2, V2-2 | Pin 1, V2-2 | 26 |
| Pin 7, V2-2 | Pin 7, V3-2 | 15 |
| Pin 7, V3-2 | Pin 2, V3-2 | 22 |
| Pin 2, V3-2 | Pin 1, V3-2 | 22 |
| Pin 1, V3-2 | Terminal 5, T1-2 | 6 |

PARTS LIST

MODEL PFA 22
PEN FUNCTION AMPLIFIER
MANUFACTURERS' CODE LETTERS

| Code | Manufacturer |
|---|---|
| A | Aerovox Corporation |
| AB | Allen-Bradley Co. |
| AP | Airpax Products Co. |
| CD | Cornell-Dubilier |
| CE | Cannon Electric Co. |
| CH | Cutler-Hammer, Inc. |
| GE | General Electric Company |
| O | Ohmite Manufacturing Co. |
| P | Pace Electrical Instruments Co., Inc. |
| SA | Scientific-Atlanta, Inc. |
| SE | Simpson Electric Company |
| T | Triad Transformer Corp. |
| TE | Transitron Electronic Corp. |

# PARTS LIST
## MODEL PFA 22
## PEN FUNCTION AMPLIFIER

| Component Designation | Description | Mfr.* | Mfr. Part No. |
|---|---|---|---|
| C1A/B/C-2 | Capacitor: fixed, electrolytic 10-10-10 μfd, 300 V DCW | A | AFH 3-22 |
| C2-2<br>C7-2<br>C10-2 | Capacitor: fixed, electrolytic 25 μfd, 25 V DCW | A | PWE 25025 |
| C3-2 | Capacitor: fixed, paper 0.01 μfd, 400 V DCW | CD | WMF4S1E |
| C4-2 | Capacitor: fixed, paper 0.047 μfd, 400 V DCW | CD | WMF4S47E |
| C5-2<br>C6-2<br>C9-2<br>C12-2 | Capacitor: fixed, paper 0.0047 μfd, 400 V DCW | CD | WMF4D47E |
| C8-2 | Capacitor: fixed, ceramic 470 μμfd, 1 KV DCW | A | BC |
| C11-2 | Capacitor: fixed, paper 0.022 μfd, 400 V DCW | CD | WMF4S22E |
| CR1-2<br>CR2-2<br>CR6-2 | Diode: silicon | TE | 1N277 |
| CR3-2 | Diode: silicon | TE | SG-22 |
| CR5-2 | Diode: silicon | TE | TJ40A |
| M1-2 | Meter: signal level | P | APR-EA-0213 |
| J2-2 | Connector: miniature, AN type | AP | 165-16 |
| J4-2 | Connector: miniature, AN type | AP | 97-3106A-14S-65 |
| P1-2 | Connector: miniature, AN type | AP | 165-15 |
| P3-2 | Connector: miniature, AN type | AP | 165-13 |
| P-3 | Potentiometer: logarithmic, plug-in | SA | P-3 |

* See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST, Continued

MODEL PFA 22

PEN FUNCTION AMPLIFIER

| Component Designation | Description | Mfr.* | Mfr. Part No. |
|---|---|---|---|
| R1-2<br>R29-2 | Resistor: fixed, composition<br>100 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R2-2 | Resistor: fixed, composition<br>2.2 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R3-2<br>R5-2 | Resistor: fixed, composition<br>1 megohm, 10%, 1/2 watt | O | "Little Devil" |
| R4-2 | Resistor: variable, composition<br>1 megohm, 10%, 2 watts | AB | JU 1052 |
| R6-2 | Resistor: fixed, composition<br>8.2 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R7-2<br>R9-2<br>R21-2<br>R25-2<br>R31-2<br>R34-2 | Resistor: fixed, composition<br>470 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R8-2 | Resistor: fixed, composition<br>3.9 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R10-2 | Resistor: fixed, composition<br>680 ohms, 10%, 1/2 watt | O | "Little Devil" |
| R11-2<br>R13-2<br>R40-2<br>R53-2 | Resistor: fixed, composition<br>10 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R33-2 | Resistor: fixed, composition<br>8.2 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R12-2 | Resistor: fixed, composition<br>47 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R14-2 | Resistor: variable, wirewound<br>5 k ohms, 10%, 2 watts | CE | 0250L-2 |
| R15-2 | Resistor: fixed, composition<br>4.7 k ohms, 10%, 1 watt | O | "Little Devil" |
| R19-2 | Resistor: fixed, composition<br>4.7 ohms, 10%, 1/2 watt | O | "Little Devil" |

* See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST, Continued

MODEL PFA 22

PEN FUNCTION AMPLIFIER

| Component Designation | Description | Mfr.* | Mfr. Part No. |
|---|---|---|---|
| R20-2 | Resistor: fixed, composition 3.3 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R22-2 | Resistor: variable, composition 250 k ohms, 10%, 2 watts | AB | JLU 2541 |
| R23-2<br>R26-2<br>R43-2 | Resistor: fixed, composition 270 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R24-2 | Resistor: fixed, composition 5.6 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R27-2 | Resistor: fixed, composition 390 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R28-2 | Resistor: fixed, composition 2.7 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R30-2 | Resistor: fixed, composition 1 k ohms, 10%, 1 watt | O | "Little Devil" |
| R32-2 | Resistor: fixed, composition 820 ohms, 10%, 1 watt | O | "Little Devil" |
| R35-2<br>R54-2 | Resistor: fixed, composition 10 ohms, 10%, 1/2 watt | O | "Little Devil" |
| R41-2 | Resistor: fixed, composition 27 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R42-2 | Resistor: fixed, composition 180 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R46-2 | Resistor: fixed, composition 12 k ohms, 10%, 1/2 watt | O | "Little Devil" |
| R47-2 | Resistor: fixed, composition 2.2 megohms, 10%, 1/2 watt | O | "Little Devil" |
| R48-2 | Resistor: variable, composition 10 k ohms, 10%, 2 watts | AB | JLU 1031 |
| S1-2 | Switch: toggle, bat handle S P D T, center off position | CH | 7581-K6 |

* See "TABLE OF MANUFACTURERS' CODE LETTERS"

PARTS LIST - Continued

MODEL PFA 22

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| Component Designation | Description | Mfr.* | Mfr. Part No. |
|---|---|---|---|
| T1-2 | Transformer: interstage | T | JO13 |
| V1-2 | Tube: electron, 12AX7 | GE | 12AX7 |
| V2-2 | Tube: electron, 12AY7 | GE | 12AY7 |
| V3-2 | Tube: electron, 12AU7 | GE | 12AU7 |

*See "TABLE OF MANUFACTURERS' CODE LETTERS"

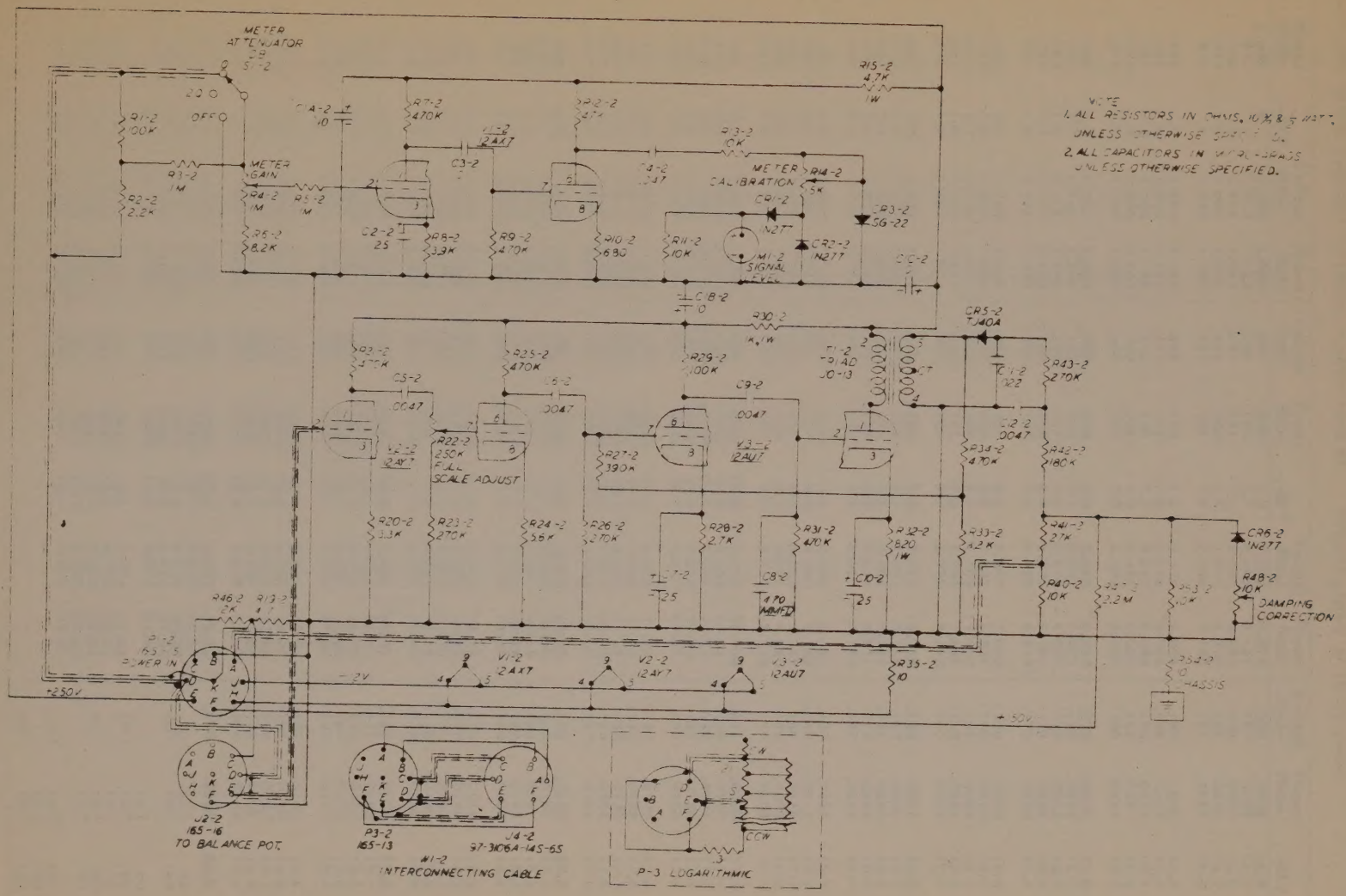


Figure 1. Model PFA 22 Pen Function Amplifier Circuit Diagram (Logarithmic).

# CONVERSION OF VOLTAGE AND POWER RATIOS TO DECIBELS

The basic chart below indicates the number of decibels (db) corresponding to the listed ratios of voltage or power over the range of −20 to +20 db. For voltage or power ratios greater than those included in the chart, the ratio can be broken down into a product of two numbers, the value in db for each found separately, and the two results added. Example: To convert a power ratio of 2,000:1 to db, express 2,000 as $2 \times 10^3$; the number of db corresponding to a power ratio of 2 is very nearly 3, and the number of db for a power ratio of $10^3$ is 30. Therefore, the power ratio of 2,000:1 is approximately 30 db + 3 db = 33 db. In the lower right-hand corner of the chart db values for voltage and power ratios of integral powers of 10 are given.

| *Voltage Ratio* | *Power Ratio* | *—db+* | *Voltage Ratio* | *Power Ratio* | *Voltage Ratio* | *Power Ratio* | *—db+* | *Voltage Ratio* | *Power Ratio* | *Voltage Ratio* | *Power Ratio* | *—db+* | *Voltage Ratio* | *Power Ratio* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1.000** | **1.000** | **0** | **1.000** | **1.000** | **.447** | **.200** | **7.0** | **2.239** | **5.012** | **.200** | **.0398** | **14.0** | **5.012** | **25.12** |
| .989 | .977 | .1 | 1.012 | 1.023 | .442 | .195 | 7.1 | 2.265 | 5.129 | .197 | .0389 | 14.1 | 5.070 | 25.70 |
| .977 | .955 | .2 | 1.023 | 1.047 | .437 | .191 | 7.2 | 2.291 | 5.248 | .195 | .0380 | 14.2 | 5.129 | 26.30 |
| .966 | .933 | .3 | 1.035 | 1.072 | .432 | .186 | 7.3 | 2.317 | 5.370 | .193 | .0372 | 14.3 | 5.188 | 26.92 |
| .955 | .912 | .4 | 1.047 | 1.096 | .427 | .182 | 7.4 | 2.344 | 5.495 | .191 | .0363 | 14.4 | 5.248 | 27.54 |
| .944 | .891 | .5 | 1.059 | 1.122 | .422 | .178 | 7.5 | 2.371 | 5.623 | .188 | .0355 | 14.5 | 5.309 | 28.18 |
| .933 | .871 | .6 | 1.072 | 1.148 | .417 | .174 | 7.6 | 2.399 | 5.754 | .186 | .0347 | 14.6 | 5.370 | 28.84 |
| .923 | .851 | .7 | 1.084 | 1.175 | .412 | .170 | 7.7 | 2.427 | 5.888 | .184 | .0339 | 14.7 | 5.433 | 29.51 |
| .912 | .832 | .8 | 1.096 | 1.202 | .407 | .166 | 7.8 | 2.455 | 6.026 | .182 | .0331 | 14.8 | 5.495 | 30.20 |
| .902 | .813 | .9 | 1.109 | 1.230 | .403 | .162 | 7.9 | 2.483 | 6.166 | .180 | .0324 | 14.9 | 5.559 | 30.90 |
| **.891** | **.794** | **1.0** | **1.122** | **1.259** | **.398** | **.159** | **8.0** | **2.512** | **6.310** | **.178** | **.0316** | **15.0** | **5.623** | **31.62** |
| .881 | .776 | 1.1 | 1.135 | 1.288 | .394 | .155 | 8.1 | 2.541 | 6.457 | .176 | .0309 | 15.1 | 5.689 | 32.36 |
| .871 | .759 | 1.2 | 1.148 | 1.318 | .389 | .151 | 8.2 | 2.570 | 6.607 | .174 | .0302 | 15.2 | 5.754 | 33.11 |
| .861 | .741 | 1.3 | 1.161 | 1.349 | .385 | .148 | 8.3 | 2.600 | 6.761 | .172 | .0295 | 15.3 | 5.821 | 33.88 |
| .851 | .724 | 1.4 | 1.175 | 1.380 | .380 | .145 | 8.4 | 2.630 | 6.918 | .170 | .0288 | 15.4 | 5.888 | 34.67 |
| .841 | .708 | 1.5 | 1.189 | 1.413 | .376 | .141 | 8.5 | 2.661 | 7.079 | .168 | .0282 | 15.5 | 5.957 | 35.48 |
| .832 | .692 | 1.6 | 1.202 | 1.445 | .372 | .138 | 8.6 | 2.692 | 7.244 | .166 | .0275 | 15.6 | 6.026 | 36.31 |
| .822 | .676 | 1.7 | 1.216 | 1.479 | .367 | .135 | 8.7 | 2.723 | 7.413 | .164 | .0269 | 15.7 | 6.095 | 37.15 |
| .813 | .661 | 1.8 | 1.230 | 1.514 | .363 | .132 | 8.8 | 2.754 | 7.586 | .162 | .0263 | 15.8 | 6.166 | 38.02 |
| .804 | .646 | 1.9 | 1.245 | 1.549 | .359 | .129 | 8.9 | 2.786 | 7.762 | .160 | .0257 | 15.9 | 6.237 | 38.90 |
| **.794** | **.631** | **2.0** | **1.259** | **1.585** | **.355** | **.126** | **9.0** | **2.818** | **7.943** | **.159** | **.0251** | **16.0** | **6.310** | **39.81** |
| .785 | .617 | 2.1 | 1.274 | 1.622 | .351 | .123 | 9.1 | 2.851 | 8.128 | .157 | .0246 | 16.1 | 6.383 | 40.74 |
| .776 | .603 | 2.2 | 1.288 | 1.660 | .347 | .120 | 9.2 | 2.884 | 8.318 | .155 | .0240 | 16.2 | 6.457 | 41.69 |
| .767 | .589 | 2.3 | 1.303 | 1.698 | .343 | .118 | 9.3 | 2.917 | 8.511 | .153 | .0234 | 16.3 | 6.531 | 42.66 |
| .759 | .575 | 2.4 | 1.318 | 1.738 | .339 | .115 | 9.4 | 2.951 | 8.710 | .151 | .0229 | 16.4 | 6.607 | 43.65 |
| .750 | .562 | 2.5 | 1.334 | 1.778 | .335 | .112 | 9.5 | 2.985 | 8.913 | .150 | .0224 | 16.5 | 6.683 | 44.67 |
| .741 | .550 | 2.6 | 1.349 | 1.820 | .331 | .110 | 9.6 | 3.020 | 9.120 | .148 | .0219 | 16.6 | 6.761 | 45.71 |
| .733 | .537 | 2.7 | 1.365 | 1.862 | .327 | .107 | 9.7 | 3.055 | 9.333 | .146 | .0214 | 16.7 | 6.839 | 46.77 |
| .724 | .525 | 2.8 | 1.380 | 1.905 | .324 | .105 | 9.8 | 3.090 | 9.550 | .145 | .0209 | 16.8 | 6.918 | 47.86 |
| .716 | .513 | 2.9 | 1.396 | 1.950 | .320 | .102 | 9.9 | 3.126 | 9.772 | .143 | .0204 | 16.9 | 6.998 | 48.98 |
| **.708** | **.501** | **3.0** | **1.413** | **1.995** | **.316** | **.100** | **10.0** | **3.162** | **10.000** | **.141** | **.0200** | **17.0** | **7.079** | **50.12** |
| .700 | .490 | 3.1 | 1.429 | 2.042 | .313 | .0977 | 10.1 | 3.199 | 10.23 | .140 | .0195 | 17.1 | 7.161 | 51.29 |
| .692 | .479 | 3.2 | 1.445 | 2.089 | .309 | .0955 | 10.2 | 3.236 | 10.47 | .138 | .0191 | 17.2 | 7.244 | 52.48 |
| .684 | .468 | 3.3 | 1.462 | 2.138 | .306 | .0933 | 10.3 | 3.273 | 10.72 | .137 | .0186 | 17.3 | 7.328 | 53.70 |
| .676 | .457 | 3.4 | 1.479 | 2.188 | .302 | .0912 | 10.4 | 3.311 | 10.96 | .135 | .0182 | 17.4 | 7.413 | 54.95 |
| .668 | .447 | 3.5 | 1.496 | 2.239 | .299 | .0891 | 10.5 | 3.350 | 11.22 | .133 | .0178 | 17.5 | 7.499 | 56.23 |
| .661 | .437 | 3.6 | 1.514 | 2.291 | .295 | .0871 | 10.6 | 3.388 | 11.48 | .132 | .0174 | 17.6 | 7.586 | 57.54 |
| .653 | .427 | 3.7 | 1.531 | 2.344 | .292 | .0851 | 10.7 | 3.428 | 11.75 | .130 | .0170 | 17.7 | 7.674 | 58.88 |
| .646 | .417 | 3.8 | 1.549 | 2.399 | .288 | .0832 | 10.8 | 3.467 | 12.02 | .129 | .0166 | 17.8 | 7.762 | 60.26 |
| .638 | .407 | 3.9 | 1.567 | 2.455 | .285 | .0813 | 10.9 | 3.508 | 12.30 | .127 | .0162 | 17.9 | 7.852 | 61.66 |
| **.631** | **.398** | **4.0** | **1.585** | **2.512** | **.282** | **.0794** | **11.0** | **3.548** | **12.59** | **.126** | **.0159** | **18.0** | **7.943** | **63.10** |
| .624 | .389 | 4.1 | 1.603 | 2.570 | .279 | .0776 | 11.1 | 3.589 | 12.88 | .125 | .0155 | 18.1 | 8.035 | 64.57 |
| .617 | .380 | 4.2 | 1.622 | 2.630 | .275 | .0759 | 11.2 | 3.631 | 13.18 | .123 | .0151 | 18.2 | 8.128 | 66.07 |
| .610 | .372 | 4.3 | 1.641 | 2.692 | .272 | .0741 | 11.3 | 3.673 | 13.49 | .122 | .0148 | 18.3 | 8.222 | 67.61 |
| .603 | .363 | 4.4 | 1.660 | 2.754 | .269 | .0724 | 11.4 | 3.715 | 13.80 | .120 | .0145 | 18.4 | 8.318 | 69.18 |
| .596 | .355 | 4.5 | 1.679 | 2.818 | .266 | .0708 | 11.5 | 3.758 | 14.13 | .119 | .0141 | 18.5 | 8.414 | 70.79 |
| .589 | .347 | 4.6 | 1.698 | 2.884 | .263 | .0692 | 11.6 | 3.802 | 14.45 | .118 | .0138 | 18.6 | 8.511 | 72.44 |
| .582 | .339 | 4.7 | 1.718 | 2.951 | .260 | .0676 | 11.7 | 3.846 | 14.79 | .116 | .0135 | 18.7 | 8.610 | 74.13 |
| .575 | .331 | 4.8 | 1.738 | 3.020 | .257 | .0661 | 11.8 | 3.890 | 15.14 | .115 | .0132 | 18.8 | 8.710 | 75.86 |
| .569 | .324 | 4.9 | 1.758 | 3.090 | .254 | .0646 | 11.9 | 3.936 | 15.49 | .114 | .0129 | 18.9 | 8.811 | 77.62 |
| **.562** | **.316** | **5.0** | **1.778** | **3.162** | **.251** | **.0631** | **12.0** | **3.981** | **15.85** | **.112** | **.0126** | **19.0** | **8.913** | **79.43** |
| .556 | .309 | 5.1 | 1.799 | 3.236 | .248 | .0617 | 12.1 | 4.027 | 16.22 | .111 | .0123 | 19.1 | 9.016 | 81.28 |
| .550 | .302 | 5.2 | 1.820 | 3.311 | .246 | .0603 | 12.2 | 4.074 | 16.60 | .110 | .0120 | 19.2 | 9.120 | 83.18 |
| .543 | .295 | 5.3 | 1.841 | 3.388 | .243 | .0589 | 12.3 | 4.121 | 16.98 | .108 | .0118 | 19.3 | 9.226 | 85.11 |
| .537 | .288 | 5.4 | 1.862 | 3.467 | .240 | .0575 | 12.4 | 4.169 | 17.38 | .107 | .0115 | 19.4 | 9.333 | 87.10 |
| .531 | .282 | 5.5 | 1.884 | 3.548 | .237 | .0562 | 12.5 | 4.217 | 17.78 | .106 | .0112 | 19.5 | 9.441 | 89.13 |
| .525 | .275 | 5.6 | 1.905 | 3.631 | .234 | .0550 | 12.6 | 4.266 | 18.20 | .105 | .0110 | 19.6 | 9.550 | 91.20 |
| .519 | .269 | 5.7 | 1.928 | 3.715 | .232 | .0537 | 12.7 | 4.315 | 18.62 | .104 | .0107 | 19.7 | 9.661 | 93.33 |
| .513 | .263 | 5.8 | 1.950 | 3.802 | .229 | .0525 | 12.8 | 4.365 | 19.05 | .102 | .0105 | 19.8 | 9.772 | 95.50 |
| .507 | .257 | 5.9 | 1.972 | 3.890 | .227 | .0513 | 12.9 | 4.416 | 19.50 | .101 | .0102 | 19.9 | 9.886 | 97.72 |
| **.501** | **.251** | **6.0** | **1.995** | **3.981** | **.224** | **.0501** | **13.0** | **4.467** | **19.95** | **.100** | **.0100** | **20.0** | **10.000** | **100.00** |
| .496 | .246 | 6.1 | 2.018 | 4.074 | .221 | .0490 | 13.1 | 4.519 | 20.42 | | | | | |
| .490 | .240 | 6.2 | 2.042 | 4.169 | .219 | .0479 | 13.2 | 4.571 | 20.89 | $10^{-2}$ | $10^{-3}$ | 30 | | $10^{3}$ |
| .484 | .234 | 6.3 | 2.065 | 4.266 | .216 | .0468 | 13.3 | 4.624 | 21.38 | | $10^{-4}$ | 40 | $10^{2}$ | $10^{4}$ |
| .479 | .229 | 6.4 | 2.089 | 4.365 | .214 | .0457 | 13.4 | 4.677 | 21.88 | | $10^{-5}$ | 50 | | $10^{5}$ |
| .473 | .224 | 6.5 | 2.113 | 4.467 | .211 | .0447 | 13.5 | 4.732 | 22.39 | $10^{-3}$ | $10^{-6}$ | 60 | $10^{3}$ | $10^{6}$ |
| .468 | .219 | 6.6 | 2.138 | 4.571 | .209 | .0437 | 13.6 | 4.786 | 22.91 | | $10^{-7}$ | 70 | | $10^{7}$ |
| .462 | .214 | 6.7 | 2.163 | 4.677 | .207 | .0427 | 13.7 | 4.842 | 23.44 | $10^{-4}$ | $10^{-8}$ | 80 | $10^{4}$ | $10^{8}$ |
| .457 | .209 | 6.8 | 2.188 | 4.786 | .204 | .0417 | 13.8 | 4.898 | 23.99 | | $10^{-9}$ | 90 | | $10^{9}$ |
| .452 | .204 | 6.9 | 2.213 | 4.898 | .202 | .0407 | 13.9 | 4.955 | 24.55 | $10^{-5}$ | $10^{-10}$ | 100 | $10^{5}$ | $10^{10}$ |
| | | | | | | | | | | | $10^{-11}$ | 110 | | $10^{11}$ |
| | | | | | | | | | | $10^{-6}$ | $10^{-12}$ | 120 | $10^{6}$ | $10^{12}$ |


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